

The Abundance and Significance of Ultraplankton and Micro-algae at an Offshore Station in Central Lake Superior

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December, 1982

THE ABUNDANCE AND SIGNIFICANCE OF ULTRAPLANKTON AND MICRO-ALGAE AT AN
OFFSHORE STATION IN CENTRAL LAKE SUPERIOR

BY

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ABSTRACT

Munawar, M. and G.L. Fahnenstiel. 1982. The abundance and significance of ultraplankton and micro-algae at an offshore station in central Lake Superior. Can. Tech. Rep. Fish. Aquat. Sci., 1153 pages i - vi, 1 -13.

Determinations of chlorophyll-a and in situ Carbon-14 uptake were made on fractionated water samples from three depths at an offshore station in central Lake Superior each month from May to October, 1979. The mean chlorophyll-a concentration data indicated that 91 percent of the pigment was found in the nanoplankton ($< 64\mu\text{m}$), and only 9 percent in the netplankton ($> 64\mu\text{m}$). The μ -algae or picoplankton ($< 3\mu\text{m}$) and ultraplankton (5 to $20\mu\text{m}$) components of the nanoplankton contained concentrations of chlorophyll-a of 42 and 25 percent of the pigment respectively. Similarly a mean Carbon-14 uptake value of 93 percent was found in the nanoplankton. The μ -algae and ultraplankton components were the most active of the phytoplankton assemblage, being responsible for 47 and 24 percent of the Carbon-14 uptake respectively. This dominance of minute organisms in the Lake Superior phytoplankton community metabolism is unique and suggests the need for further experimental research on the physiological basis of their active existence.

RÉSUMÉ

Munawar, M. and G.L. Fahnenstiel. 1982. The abundance and significance of ultraplankton and micro-algae at an offshore station in central Lake Superior. Can. Tech. Rep. Fish. Aquat. Sci., 1153 pages 1 - vi, 1 -13.

On a dosé la chlorophylle-a et on a déterminé l'assimilation du Carbone-14 in situ dans des échantillons fractionnés d'eau prélevés à trois profondeurs dans une station située au centre du lac Supérieur, tous les mois, de mai à octobre 1979. Les données sur la concentration moyenne de chlorophylle-a ont révélé que 91 p. cent du pigment se trouvait dans le nanoplankton ($< 64\mu\text{m}$) et seulement 9 p. cent dans le plancton tamisé ($> 64\mu\text{m}$). Les micro-algues ou picoplankton ($< 3\mu\text{m}$), et les constituants de l'ultraplancton (5 to $20\mu\text{m}$) renfermaient des concentrations de chlorophylle-a correspondant à 42 et 25 p. cent du pigment, respectivement. De la même façon, on a trouvé une assimilation du Carbone-14 moyenne équivalente à 93 p. cent dans le nanoplankton. Les micro-algues et les constituants de l'ultraplancton étaient les organismes les plus actifs du phytoplancton, en contribuant à 47 et 24 p. cent de l'assimilation du Carbone-14, respectivement. Cette dominance des micro-organismes dans le métabolisme du phytoplancton du lac Supérieur est unique; c'est pourquoi il faudrait entreprendre des recherches expérimentales plus poussées sur la base physiologique de leur existence active.

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INTRODUCTION

Considerable phycological information has been made available about the St. Lawrence Great Lakes during the past decade (eg. Munawar and Nauwerck, 1971; Munawar and Munawar, 1975; Vollenweider et al . 1974; and Munawar and Munawar, 1982). This data also includes detailed information about the size structure of the phytoplankton assemblages, so essential in the understanding of lake dynamics (Munawar et al . 1974; Munawar et al . 1978; and Munawar and Munawar, 1981). These data emphasize the abundance of nanoplankton ($<64\mu\text{m}$) and the dominance of small sized organisms ($<10\mu\text{m}$) in the Great Lakes (Munawar and Munawar, 1978; Munawar et al . 1978). This report is a continuation of our interest in the size spectrum of phytoplankton and nanoplankton dynamics as shown by pigment content and photosynthetic Carbon-14 uptake. The research reported here represents a detailed phycological study at an offshore station of Lake Superior and contains considerable interesting and new data about micro-algae, also known as picoplankton ($<3\mu\text{m}$) and ultraplankton (5 to $20\mu\text{m}$) being reported for the first time.

METHODS

A series of nine phytoplankton samples were collected by a Van Dorn sampler during the period May to October, 1979, at an offshore station (depth 230 m), located 25 km from the north entrance of the portage ship canal near Houghton, Michigan (Fig. 1). In situ

carbon-14 uptake experiments were conducted in 300ml glass bottles at three depths namely 5, 10, and 25 meters which were inoculated by $H^{14}CO_3^-$ and suspended at appropriate depths for four hours. After the incubation period, the bottles were retrieved for filtration. One portion of the sample (unfractionated) served as control and was filtered directly through a $0.45\mu m$ Selectron membrane filter. The remaining portion was filtered through 64 , 20 , and $10\mu m$ Nitex screens, and 3 & $5\mu m$ Nuclepore filters. Immediately after filtration, filters were fumed over concentrated HCl for five to six minutes to remove inorganic C-14 (Williams et al . 1972). Filters were then placed in vials containing 10ml of Aquasol. Activities of each filter were counted on a Packard 3310 liquid scintillation counter until 20,000 counts were recorded. The channels ratio method was used to correct for quench. Production calculations were made according to Vollenweider (1974).

Chlorophyll-a was determined fluorometrically according to Strickland and Parsons (1968). Chlorophyll-a obtained from Sigma Chemical Co. was used for calibrating the doors and windows used. Selectron membrane filters were used instead of glass fibre filters because of poor retention of particles in the latter (Munawar et al . 1982). After filtration the filters were mixed for one minute with a vortex mixer and then extracted for 18 to 20 hours in the dark, followed by centrifugation for 15 minutes at 3000 rpm. All chlorophyll-a values were corrected for phaeophytin. Size fractionation of chlorophyll-a was similar to the procedure followed for Carbon-14 uptake fractionation.

The terminology followed for size fractionation by Munawar et al . (1978) has been adopted: organisms passing through a 64 μ m screen are referred to as nanoplankton, whereas those retained on a 64 μ m screen will be referred to as netplankton. The organisms which pass through a 3 μ m membrane have been termed as μ -algae (also referred to by others as picoplankton). Similarly, organisms which pass through a 5 μ m membrane but retained on a 20 μ m Nitex screen are called ultraplankton (5 to 20 μ m). The species composition of Lugol's preserved samples was carried out by the Utermohl technique (Munawar et al . 1974).

RESULTS & DISCUSSION

The chlorophyll-a concentration and its percent composition by size are given in Tables 1 and 2. As far as the temperature regime is concerned, the periods of May to July, and October, represented the isothermal conditions at the sampling station. On the other hand, the stratified conditions prevailed during August and September. The highest concentration of chlorophyll-a was contained in nanoplankton throughout the period of study. During isothermal conditions chlorophyll-a concentration was more or less similar at the three depths sampled. The μ -algae had the highest concentration of chlorophyll-a with little variability from 5 to 25 metres. Ultraplankton (5 to 20 μ m) were the second most abundant size fraction of phytoplankton which contained high concentrations of chlorophyll-a.

During stratified conditions highest concentrations of chlorophyll-a were observed at 15 metres depth (Tables 1 and 2). The μ -algae or picoplankton ($<3\mu\text{m}$) and ultraplankton continued to harbour a major portion of the pigments. An average for the entire study period of 43 percent and 25 percent of chlorophyll-a was contributed by μ -algae and ultraplankton respectively.

The results of Carbon-14 uptake profiles and their size fractionation is shown in Tables 3 and 4. Similar to the pigments, the nanoplankton were responsible for the highest Carbon-14 uptake throughout the study period. During the isothermal conditions, with the exception of October, slightly higher Carbon-14 uptake was observed at 15 and 25 metres. The highest uptake was exhibited by the μ -algae followed by ultraplankton, usually without much vertical variability. The Carbon-14 profile of September 4 (stratified) was unique since the highest percent μ -algae contribution was observed at the five metre depth. Furthermore, the ultraplankton showed a high uptake in this experiment, almost equal to the mean Carbon-14 uptake contribution of the μ -algae (36 percent for μ -algae versus 37 percent for ultraplankton). On an average basis, μ -algae and ultraplankton contributed as much as 47 percent and 24 percent respectively, which together accounts for more than 70 percent of the total photosynthetic uptake.

The species composition of phytoplankton at the three depths is given in Table 5. The data is restricted to those common species which contributed more than 5 percent to the total phytoplankton biomass. These data indicate that species belonging

to phytoflagellates (Cryptophyceae and Chrysophyceae) were apparently responsible for the high concentration of chlorophyll-a and photosynthetic Carbon-14 assimilation exhibited by μ -algae and ultraplankton in the present study.

These results have confirmed the earlier conclusions of Munawar et al. (1978) concerning the significance of minute organisms in the community metabolism of the Great Lakes. Furthermore, our data have demonstrated for the first time the abundance of μ -algae (picoplankton) in Lake Superior as shown by their overwhelming contribution to Chlorophyll-a and Carbon-14 uptake. Similar dominance of small sized organisms have been studied in other environments (eg. Votintsev et al., 1972; Paerl, 1972; and Johnson & Sieburth, 1979). The published work observed cells ranging from 1μ m to 3μ m and classified them to be Synechococcus or Synchocystis -like cells. Our μ -algae collections, as seen under a fluorescent microscope, consisted mainly of small ($1-2.8\mu$ m), spherical and heavily pigmented organisms. These data suggest unique ecological niches operating in an extremely oligotrophic ecosystem dominated by minute organisms. Our results also point out the need for experimental research to explore the physiological basis of the active existence of μ -algae and ultraplankton, not only in Lake Superior, but in all of the Great Lakes.

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Figure 1 ● Sampling station

Table 1: Chlorophyll-a Concentration and its Size Distribution, May to July, at an Offshore Station Near Houghton, Michigan, 1979.

Sampling Dates	May 21, 1979			June 5, 1979			June 18, 1979			July 2, 1979		
Depth - metres	5.0	15.0	25.0	5.0	15.0	25.0	5.0	15.0	25.0	5.0	15.0	25.0
Chlorophyll <u>a</u> mg/m ³	0.48	0.64	0.64	0.28	0.39	0.32	0.42	0.39	0.39	0.45	0.47	0.42
% Composition by Size												
<3 μ m	50	42	39	44	38	39	40	37	41	50	47	49
3-5 μ m	11	9	10	19	22	13	6	10	12	13	13	3
5-20 μ m	24	31	24	19	20	24	31	33	25	19	20	24
20-64 μ m	5	12	21	8	15	16	13	13	11	8	15	16
>64 μ m	10	6	5	10	5	8	10	6	11	10	5	8

* Corrected for phaeophytin

Table 2: Chlorophyll-a Concentration and its Size Distribution, July to October, at an Offshore Station Near Houghton, Michigan, 1979.

Sampling Dates	July 12, 1979			Sept 4, 1979			Sept 23, 1979			Oct 15, 1979		
Depth - metres	5.0	15.0	25.0	5.0	15.0	25.0	5.0	15.0	25.0	5.0	15.0	25.0
Chlorophyll μ mg/m ³	0.37	0.46	0.48	0.72	1.51	1.33	0.66	1.35	0.98	1.1	1.2	1.06
% Composition by Size												
<3 μ m	47	45	40	40	29	44	42	40	41	50	46	45
3- 5 μ m	4	12	10	8	14	14	9	12	17	9	12	11
5-20 μ m	26	20	28	34	36	16	35	37	12	21	19	26
20-64 μ m	13	10	13	8	8	16	7	3	20	12	14	9
>64 μ m	10	13	9	6	12	10	7	8	10	8	9	9

* Corrected for phaeophytin

Table 3: Carbon-14 Uptake and its Size Distribution, May to July, at an Offshore Station near Houton, Michigan, 1979.

Sampling Dates	May 21, 1979			June 5, 1979			June 18, 1979			July 2, 1979		
Depth - metres	5.0	15.0	25.0	5.0	15.0	25.0	5.0	15.0	25.0	5.0	15.0	25.0
Primary Production mgC/m ³ /hr.	0.36	0.58	0.51	0.68	0.96	0.76	0.62	1.0	0.94	0.36	0.85	0.89
% Composition by Size	<3 µm			47 42 48			47 50 46			50 52 55		
	3- 5 µm			15 15 16			14 10 14			21 10 7		
	5-20 µm			23 26 14			24 9 21			15 20 20		
	20-64 µm			5 8 12			10 13 13			8 14 8		
	>64 µm			10 9 10			5 11 6			6 4 10		

Table 4: Carbon-14 Uptake and its Size Distribution, July to October, at an Offshore Station Near Houghton, Michigan, 1979.

Sampling Dates	July 17, 1979			Sept 4, 1979			Sept 23, 1979			Oct 15, 1979		
Depth - metres	5.0	15.0	25.0	5.0	15.0	25.0	5.0	15.0	25.0	5.0	15.0	25.0
Primary Production mgC/m ³ /hr.	0.63	1.1	0.98	2.3	3.5	0.89	1.64	2.05	0.96	2.9	2.9	1.17
% Composition by Size	<3 µm			41			48			43		
	3- 5 µm			11			18			17		
	5-20 µm			38			24			25		
	20-64 µm			3			2			9		
	>64 µm			6			8			6		

Table 5: Common Species (greater or equal to 5% biomass) at an Offshore Station Near Houghton, Michigan, 1979.

	May 21/79			June 5/79			June 18/79			July 2 /79			July 17/79			Sept 4/79			Sept 23/79			Oct 15/79		
	5m	15m	25m	5m	15m	25m	5m	15m	25m	5m	15m	25m	5m	15m	25m	5m	15m	25m	5m	15m	25m			
<i>Oscillatoria</i> sp.				+	+	++									+									
<i>Ochromonas</i> sp.	+	++	+	+	+			+++	+++		+	++	+	++	+	+++	++		+					
<i>Chrysochromulina parva</i> Leckey							+																	
<i>Cyclotella Coma</i> (Ehr.) Kütz.										++														
<i>C. bodanica</i> Eulen						+																		
<i>Synedra</i> sp.							++	++		+	+	++	++	+	+			++						
<i>Tabellaria Flocculosa</i> (Roth) Kütz.				++																				
<i>Fragilaria crotonensis</i> Kilton										+														
<i>Cryptomonas</i> sp.	+	++	++	++	++	+++	++	++	+++	++	+	++	++	+	++			++	+++	++	++			
<i>Rhodomonas minuta</i> Skuja	+++	+++	++	++	+++	++	+	++	++	++	+	++	++	+	++	++		++	+++	++	++			
<i>Gymnodinium varians</i> Nishii			+	+			+							+										
<i>G. helveticum</i> Pennard												++								++				
<i>Peridinium</i> sp.										+						+								
																						Contribution to Biomass		

Contribution to Biomass

+ : 5-10%
 ++ : 10-20%
 +++ : 20-30%
 ++++ : 30-40%
 +++++ : 40-50%